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Robotic Vegetable Grafting

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SUMMARY

Grafting is a popular horticultural technology in vegetables especially in solanaceous and cucurbitaceous crops by using suitable and desired rootstocks. The main objective is to induce plant vigour, growth, precocity, enhanced fruit yield, quality, harvesting period, better survival rate under biotic and abiotic stress. However, manual grafting becomes laborious, time, space and material consuming. In order to overcome these problems an alternative approach of robotic grafting gives better results in the form of reduction of higher price of grafted seedlings. By using the most sophisticated machine, grafting efficiency could be significantly increased to two to three folds than the manual grafting. Hence, supply of quality grafted seedlings in large quantity is only possible with the adoption of robotic technology.

INTRODUCTION

Vegetable grafting was adopted to enhance their ability to cope up with biotic and abiotic stresses. Grafting is now common in many parts of the world not only to manage soil-borne diseases but also to improve fruit quality and crop response to a variety of abiotic stresses. Grafting also reduces dependency upon chemicals required to treat the soil to prevent soil borne diseases. The different rootstocks suitable for different purposes in vegetable crops are given as below.

Table 1: Promising rootstocks for grafting with their performances.

Root stock	Scion	Performance
S. lycopersicum L.	Tomato	Vigor and virus tolerances
		High temperature tolerance
S. lacintatum		Resistant to water-logging
S. sisymbrifolium		Disease resistance, no effect on sugar content
S. nigram		Fruit size and quality contol
S. lycopersicon		Resistant to corky rot, Root knot nematode, Verticillium wilt and Fusarium wilt.
S. torvum		Disease resistance, no effect on sugar content
S. torvum	Egg plant	Disease resistance, Resistant to nematodes
S.integrifolium x S.melongena		High temperature tolerance
Capsicum spp	Sweet pepper	Compatible with capsicum only
Lagenaria and interspecific *Cucurbita* hybrids	Water melon	Improve tolerance to root-knot nematodes
Fig leaf gourd	Cucumber	Superior cold tolerance, resistance to *Fusarium* wilt, tolerance to low soil temperature
C. maxima × *C. moschata*	Melon	Highly resistant to *Fusarium* wilt and tolerant to *Verticillium* wilt and gummy stem blight.

Robotic grafting:

There are several basic factors which govern the success of grafting by machine or robot such as seedling shape, location of cut, seedling gripping, cutting method, fixing materials and tools etc. Grafting is a procedure that has a high labour demand, particularly in large commercial nurseries, which need to produce thousands of grafting seedlings in a short period of time. It is estimated that of graft 3,000 cucumbers, 42 man hours are required, with 70% of this time being spent for the union of root stocks and scion. The need to satisfy high demand, but at the same time reduce production costs, makes the adoption of mechanization for grafting is necessity. The need to use machinery in plant production is to reduce the demand for human labor, expand production capacities, and improve product uniformity has been recognized for a long time. In advanced agricultural countries, efforts are being made to develop and use automatic graft equipment due to the lack of labor in rural areas. An improvement in grafting methods and techniques that reduce the cost of labor in grafting, its subsequent management, and transplants will contribute to the increased use of grafted plants worldwide. Machines and robots can graft as 600-1200 seedlings per hour, compared to 150-180 seedlings per hour by a specialized worker. The robotic equipment for grafting consists of transport devices, the manipulator itself, cutting mechanisms, and devices that facilitate bonding and grip. There are two types of robots: semi-automated and fully automated. For the semi-automated ones, someone has to feed the plants to the machine. For fully automated units, a person can place a tray of 100 or 200 plants into the machine, and the machine takes the plants and grafts them. In 2006, a fully automated machine was developed in the Netherlands for grafting tomatoes. Unlike semi-automated ones, all that is necessary is to have one person provide rootstock and scion trays. In 2010, the Dutch company started developing the second-generation machine, with improved operation and speed (>1,000 grafts/hour) using a grafting clip widely used by the nursery industry. The company is currently testing the machines for large-scale grafting operations. A fully automated machine was also developed for cucurbits in Japan in 2011, as an upgraded version of the semi-automated robot developed in 1990s. The robots employ suitable computer programmes that can select, sort and graft uniform seedlings. The first semi automatic cucumber grafting system was commercialized in 1993. A simple grafting machine can produce 350–600 grafts/hour with 2 operators, whereas manual grafting techniques produce about 1,000 grafts/person/ day. A fully automated grafting robot performing 750 grafts/hour with a 90-93% success rate. The grafting machines are invented by countries *viz.*, Netherlands, Spain, Italy, Israel, Japan, Korea, China, and Taiwan. Among them, the Netherlands, Spain, Italy and Israel had invented the grafting machine mainly for *solanaceous* vegetables while, Japan, Korea and China had invented for *Cucurbitaceae*.

Fig. 1 Semi-automatic grafting robot

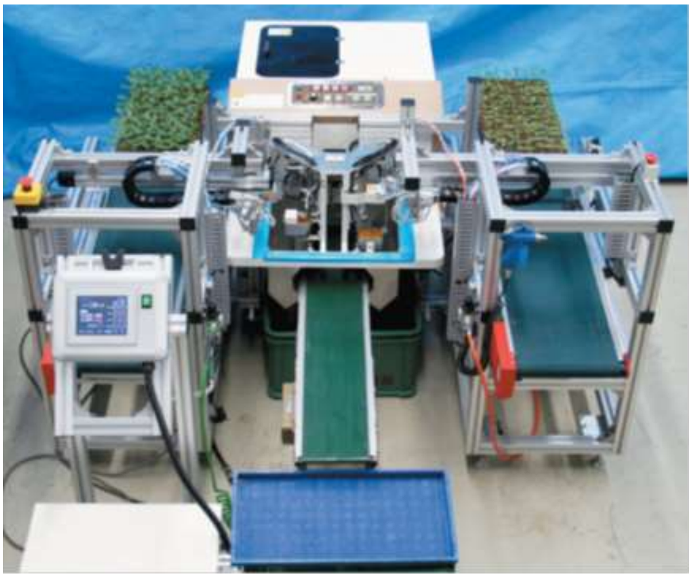

Fig. 2 Fully automated grafting robot for cucurbits (BRAIN, Saitama, Japan)

Advantages of robotic grafting:

- Automated grafting robots produce uniform seedlings at a lower cost.
- Robot-aided grafting can simplify the grafting operation.
- Improve productivity
- Improve quality of grafted seedlings.
- Labor-saving for grafting processes.
- Enhancing production environment and solving the problem of labor shortage.
- Robots are used to improve the resource utilization and agriculture output ratio.
- Reduce labor intensity and enhance economic benefits.
- Reliable operation.
- Small size, modularity of components, operator safety.
- The maximum sustainable productivity.
- Quicker, safer, high accuracy and completely automated process,

Disadvantages:

- High investment costs.
- Heterogeneity of the applicative contexts.
- Need of worker in semi-automatic robotic grafting.

CONCLUSIONS

Due to the aging and shortage of skilled agri-workers, mechanization and automation of grafting operations are necessary to develop the increasing work efficiency and productivity thus enhancing the competitiveness of the seedling industry. To reduce grafting labor costs and increase the efficiency of grafted seedling production, there is need of present days to use grafting robots.

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